(12) UK Patent Application (19) GB (11) 2 272 287 (13) A

(43) Date of A Publication 11.05.1994

(21) Application No 9323178.5

(22) Date of Filing 13.06.1991

Date Lodged 10.11.1993

(30) Priority Data

(31)	(32)	(33)
02157095	14.06.1990	JP
02305852	09.11.1990	
02305853	09.11.1990	
02341070	30.11.1990	

(62) Derived from Application No. 9112779.5 under Section 15(4) of the Patents Act 1977

(71) Applicant(s)
Tokyo Gas Company Limited

(Incorporated in Japan)

1-5-20 Kaigan, Minato-ku, Tokyo, Japan

(51) INT CL^5
G01F 25/00

(52) UK CL (Edition M)
G1G GEX

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition M) G1G GEX GPKF GPKX
INT CL^5 G01F, G01P
ONLINE DATABASES: WPI

(72) Inventor(s)
Takashi Ueki
Katsuhito Sakai
Takeshi Abe

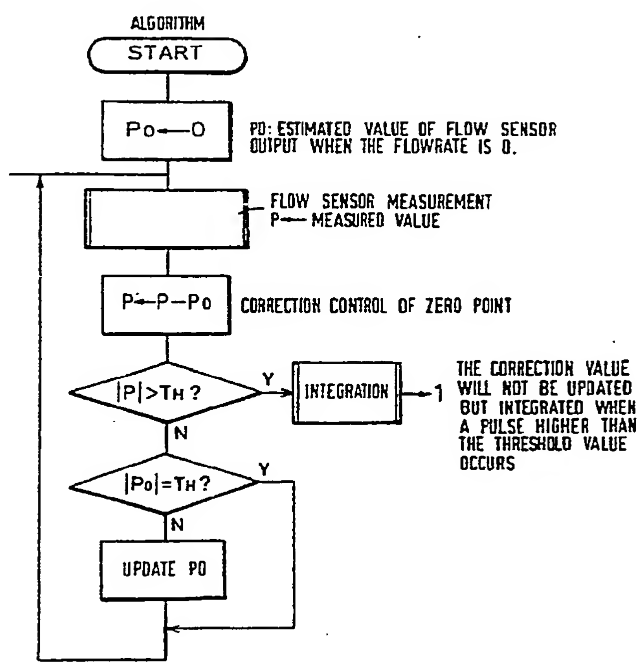
(74) Agent and/or Address for Service
Herbert J W Wildbore
73 Farringdon Road, LONDON, EC1M 3JB,
United Kingdom

BEST AVAILABLE COPY

(54) Flow sensor zero-point correction

(57) A fluid flowmeter for measuring rates of flow higher than a preset rate by means of a fluidic element (1) and lower than a preset rate by means of a flow sensor (6), a method for zero point correction of the flow sensor wherein the maximum value of the permissible shift is set as a threshold value T_H and the number of output pulses Po is assumed to be the zero point of the flow sensor for establishing the shift only when the actual value of flow sensor output P is less than the said threshold value and wherein if the number of output pulses is greater than the threshold value, the shift value is not updated assuming that there has been a flow, and the flow rate is corrected by use of the value available at that time.

FIG. 3



GB 2 272 287 A

The date of filing shown above is that provisionally accorded to the application in accordance with the provisions of Section 15(4) of the Patents Act 1977 and is subject to ratification or amendment.

F I G. 1

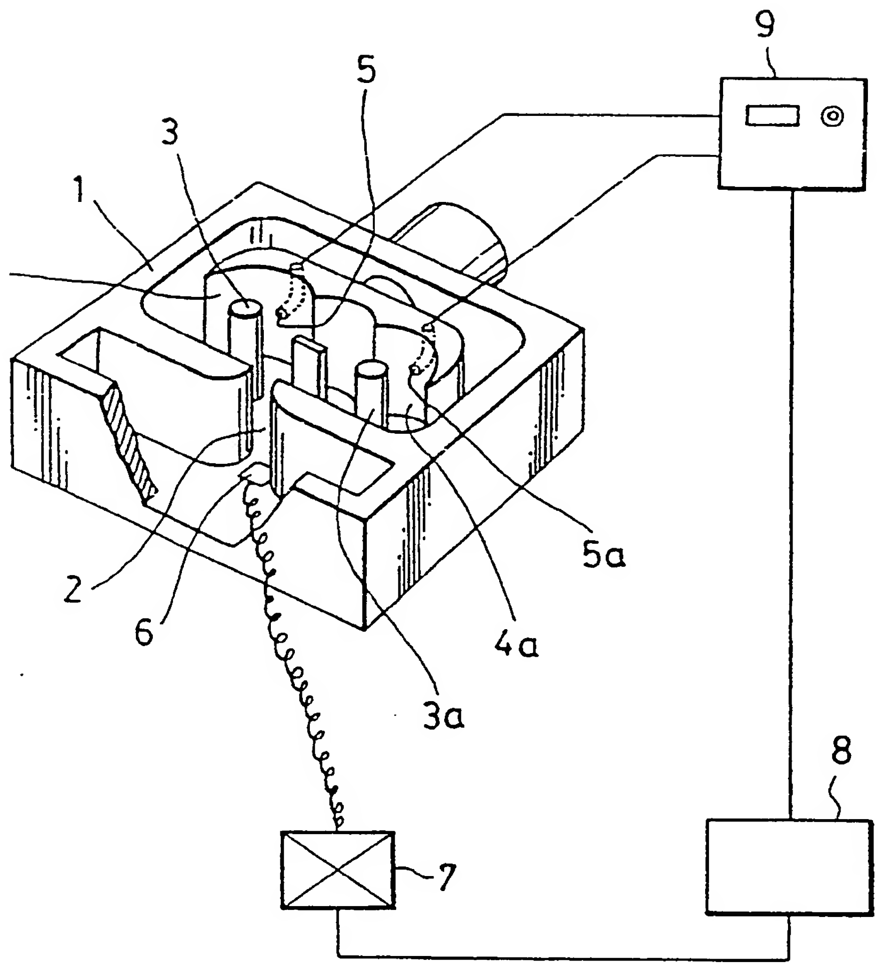


FIG. 2

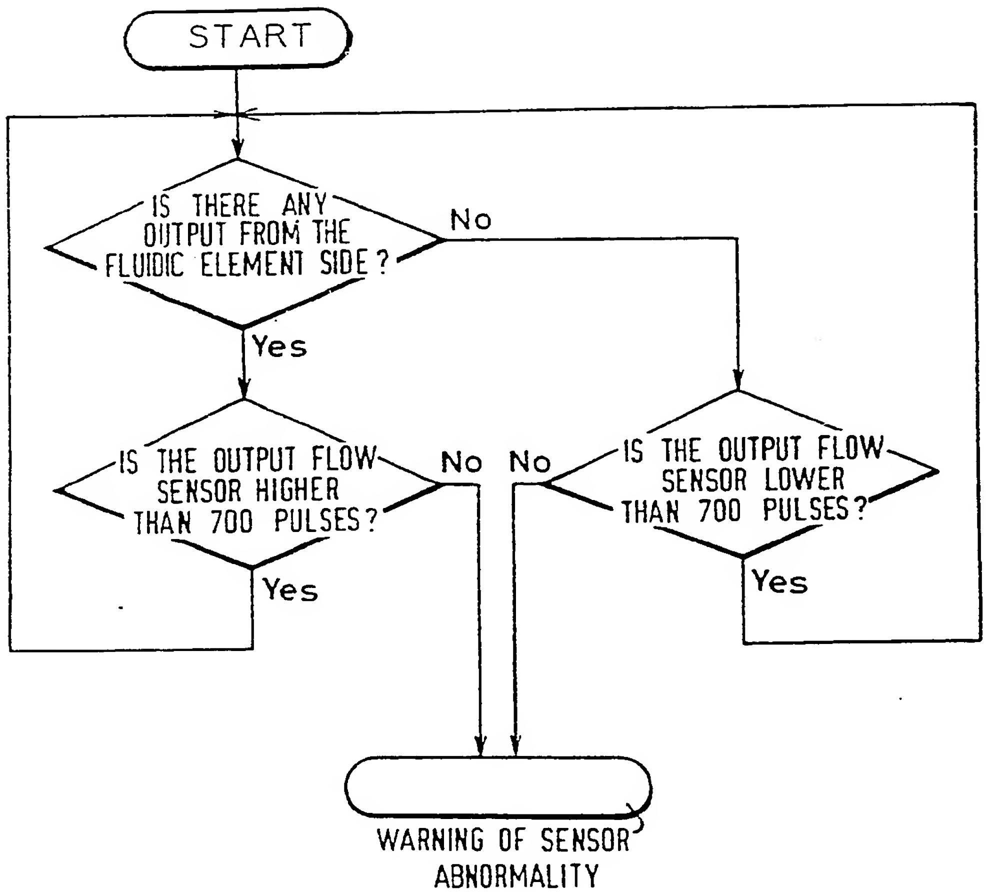

START
IS THERE ANY OUTPUT FROM THE FLUIDIC ELEMENT SIDE?
No
Yes
IS THE OUTPUT FLOW SENSOR HIGHER THAN 700 PULSES?
No
No
IS THE OUTPUT FLOW SENSOR LOWER THAN 700 PULSES?
Yes
Yes
WARNING OF SENSOR ABNORMALITY

FIG. 3

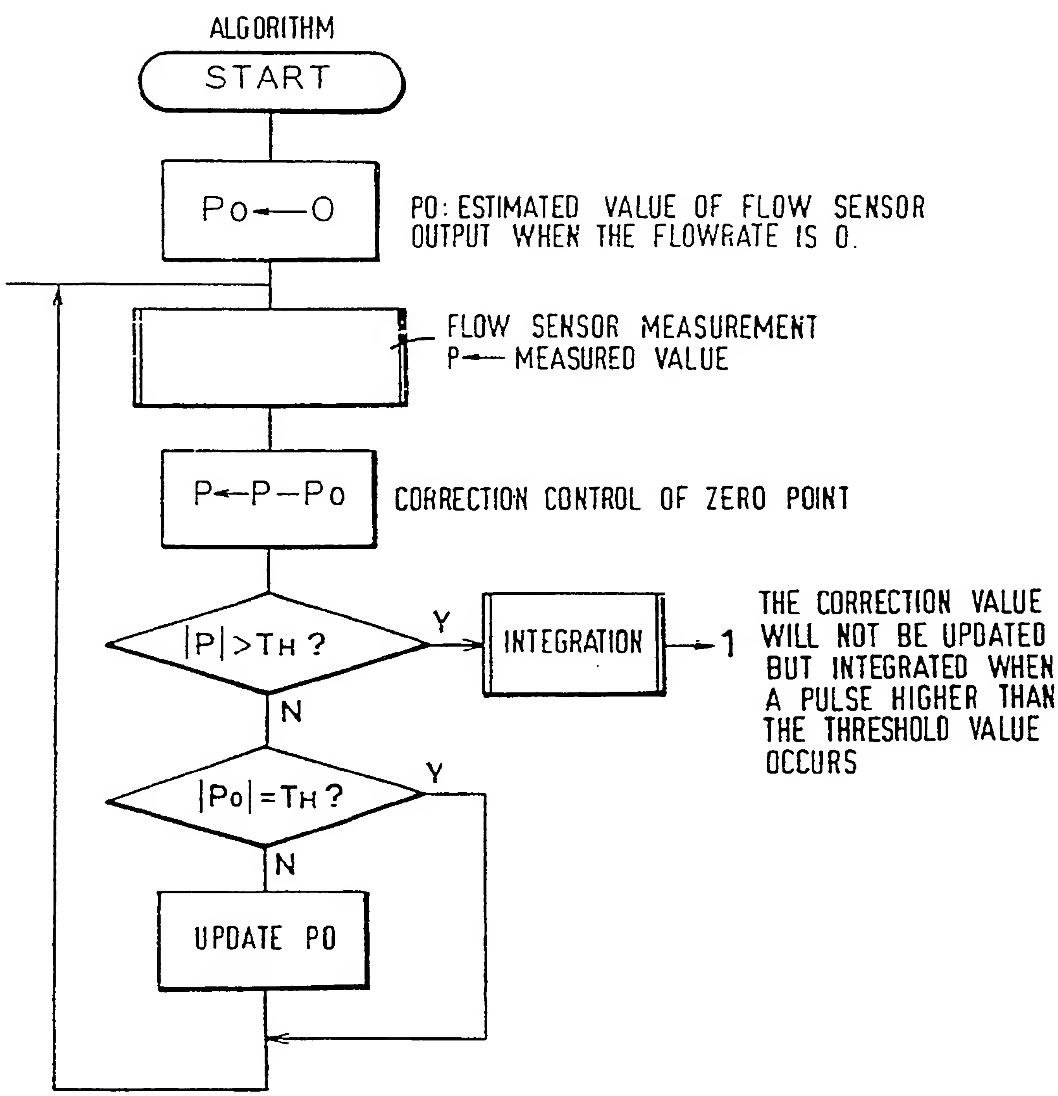
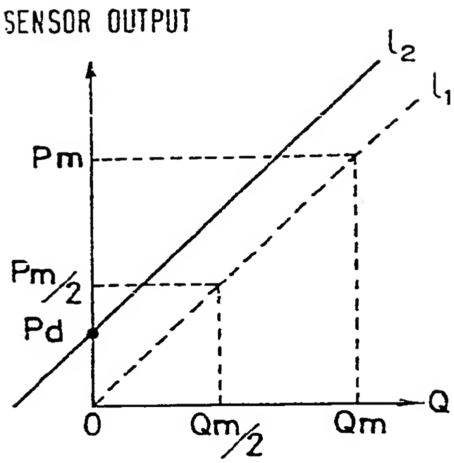
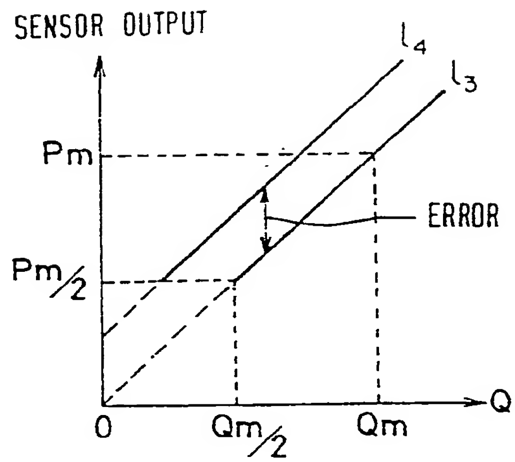

ALGORITHM
START
Po ← O
PO: ESTIMATED VALUE OF FLOW SENSOR OUTPUT WHEN THE FLOWRATE IS 0.
FLOW SENSOR MEASUREMENT
P ← MEASURED VALUE
P ← P − Po
CORRECTION CONTROL OF ZERO POINT
|P| > TH ?
Y
INTEGRATION
1
THE CORRECTION VALUE WILL NOT BE UPDATED BUT INTEGRATED WHEN A PULSE HIGHER THAN THE THRESHOLD VALUE OCCURS
N
|Po| = TH ?
Y
N
UPDATE PO

FIG. 4
(A)



(BEFORE CORRECTION)

FIG. 4
(B)



(AFTER CORRECTION)

Qm : NECESSARY MINIMUM DETECTED VALUE

l_1 : INITIAL CHARACTERISTICS OF SENSOR

Pd : ZERO POINT DRIFT OF SENSOR

l_3 : SENSOR CHARCTERISTICS AFTER THE CORRECTION

Pm : SENSOR OUTPUT CORRESPONDING TO Qm

l_2 : DRIFTED SENSOR CHARACTERISTICS

l_4 : CHARACTERISTICS AFTER CORRECTION BY THE CONVENTIONAL METHOD

FIG. 5

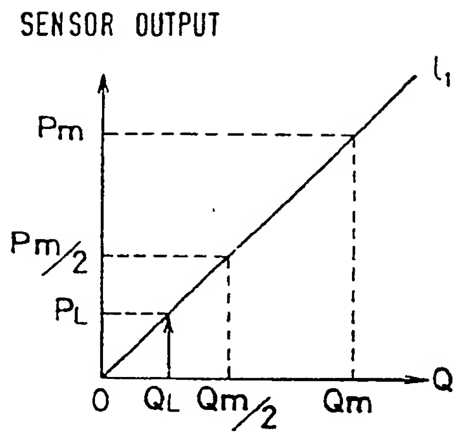


FIG. 6

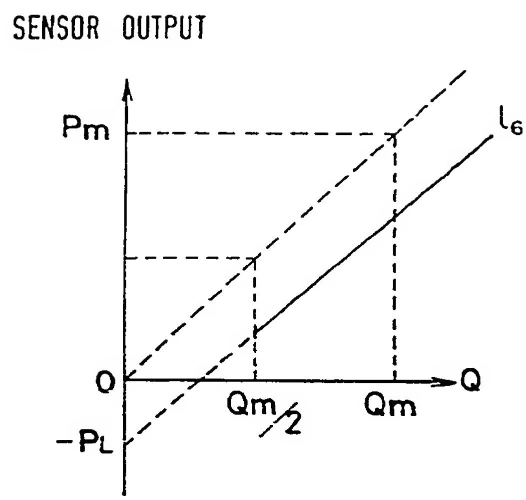


FIG. 7

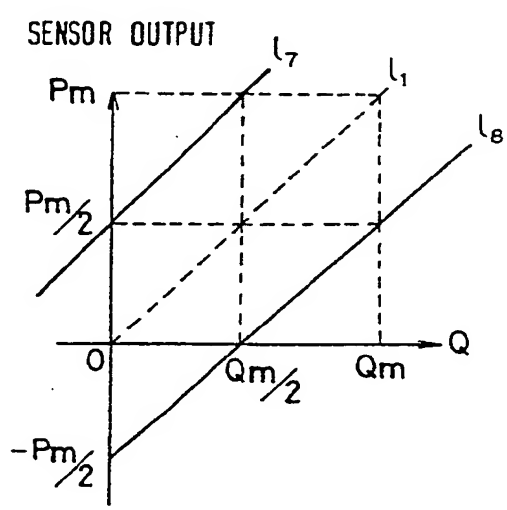


FIG. 8

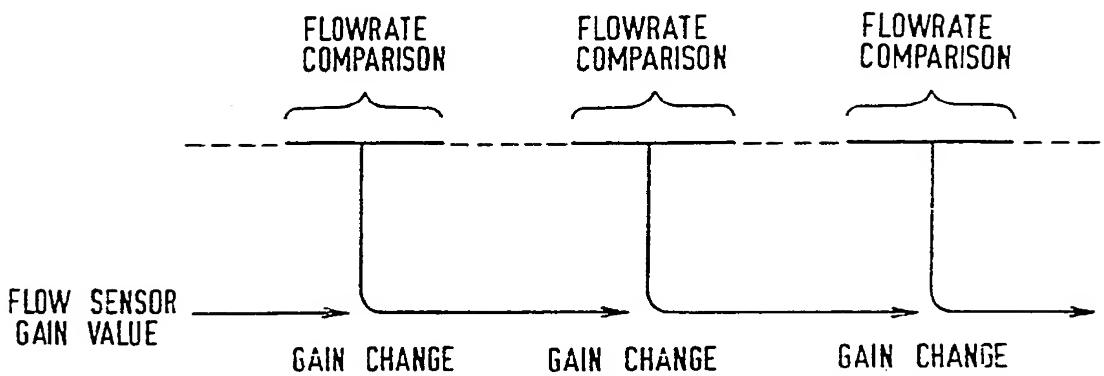
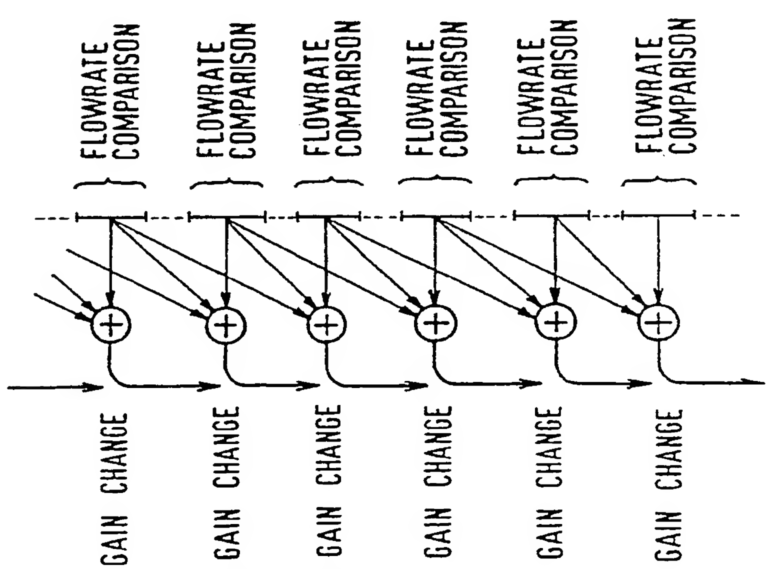


FIG. 9



(IN THE CASE OF n=3)

2272287

TITLE

Fluid Flowmeter

This invention relates to a fluid flowmeter and in particular to a method for the zero point correction of a flow sensor used in a flowmeter for determining rates of flow of gases especially gas supplied for heating and other purposes to dwellings or industrial premises. The flowmeter of this invention is constructed around a fluidic element which includes a flow attachment wall and a feedback channel to the downstream side of a nozzle whereby a fluidic oscillation is set up at the attachment wall by the Coanda effect. The oscillation is propagated by transmission to the feedback channel whereby the frequency of the oscillation can be made proportional to the fluid flow to be measured.

A fluidic element forming a flowmeter operating in this way is disclosed in U.S. Patents 3640133 and 3690171 and in Japanese Publications 48-54962, 53-77558, and 59-184822.

In such a fluid flowmeter the oscillations set up inside the fluidic element are electrically sensed and used as a measure of the rate of flow by feeding the signal to a microprocessor as example. When the rate of

flow is comparatively large the system functions satisfactorily but as the flow rate reduces to a small value the fluidic oscillation tends to become unstable resulting in substantial errors in measurement.

To overcome this disadvantage it has been proposed to provide for measurement of flow rate greater than a certain value to be effected by a fluidic element whereas a flow rate lower than a certain value is determined by means of a flow sensor located in the nozzle of the fluidic element (Japanese Publication 1-58118).

There are disadvantages in the aforementioned system in that if a cable disconnection occurs or a contact becomes defective in the flow sensor or the fluidic oscillation sensor then it is possible for an erroneous flow rate to be determined without noticing the failure. A further problem arises because the flow sensor has a high stability and is generally used without carrying out the zero point correction. Because a small deviation from the zero point is anticipated during manufacture or during use, it is usual to ignore a small range of flow rates around the zero point as being unreliable. When the output in the vicinity of zero flow rate is ignored, no correction is made regarding the zero point drift which may occur due to adjustment errors during manufacture or over an extended period of time during

use. When determining small rates of flow the value of the zero drift has a large influence on the measuring accuracy because of the relatively large value as compared with the flow rate signal output.

Whilst the flow sensor is robust, accuracy may change over a period of time due to accumulation of dust and the like particles and to overcome this a means is known for automatically correcting the inaccuracy of the flow sensor by using a comparison process between the flow sensor and the fluidic element in the region of flow where both sensors are operative.

When the pulse output of flow sensor is P, there exists the following relation against the flow rate indicated value $Q_{(FS)}$ by the flow sensor.

$$Q_{(FS)} = K^{I}_{(FS)} P. \qquad (1)$$

where $K^{i}_{(FS)}$ is the flow sensor gain at time i.

If the gas flow rate has entered a region where measurement is effected with both the flow sensor and fluidic element.

$$K^{i} = \frac{Q^{i}_{(FD)}}{P^{i}} \qquad (2)$$

where, the P^{i} is the mean value of pulse number of the flow sensor during its correction, while the $Q^{i}_{(FD)}$ is the mean value of flow rate measured by the fluidic element. In the known method, the correction is made by

using the K^i obtained by formula (2) as a new flow sensor gain. That is to say,

$$K^{i+1}{}_{(FS)} = K^i \qquad (3)$$

where the $K^{i+1}{}_{(FS)}$ is the flow sensor gain at the point of time i + 1.

In this example, although the measured values of flow sensor and fluidic element may indicate a high accuracy as a time averaged value, the value of every measurement fluctuates due to flow disturbance and noise. Therefore, to correct the flow sensor with a high accuracy, the outputs of the fluidic element and flow sensor need to be measured and averaged over many hours. However in the case of a domestic gas meter it is impossible to allow sufficient flow for test purposes and to correct the flow rate. The flow rate needs to be corrected while gas is used so a longer period required for correcting the flow rate results in a fall in the number of corrections applied. In addition, even where the noise is combined with the measured value during the correction there is no means for determining this event and hence there ~~is~~ a possibility that the error of the flow sensor will increase temporarily.

It is one of the objects of this invention to provide a method of zero point correction of a flow sensor used in a flow meter which largely avoids the

aforementioned disadvantages.

A further object of this invention is to provide a flow meter wherein a signal may be produced following failure of an electric circuit and wherein a method is provided for correcting changes in the zero point and the sensitivity of the flow sensor.

According to this invention there is provided a fluid flowmeter for measuring rates of flow higher than a preset rate by means of a fluidic element and lower than a preset rate by means of a flow sensor, a method for zero point correction of the flow sensor wherein the maximum value of the permissible shift is set as a threshold value and the number of output pulses is assumed to be the zero point of the flow sensor for establishing the shift only when the actual value of flow sensor output is less than the said threshold value and wherein if the number of output pulses is greater than the threshold value, the shift value is not updated assuming that there has been a flow, and the flow rate is corrected by use of the value available at that time.

According to this invention there is also provided a method for zero point correction of a flow sensor wherein the maximum value of the permissible shift is set as a threshold value and the number of output pulses is assumed to be the zero point of the flow sensor for

establishing the shift only when the actual value of flow sensor output is less than the said threshold value and wherein if the number of output pulses is greater than the threshold value, the shift value is not updated assuming that there has been a flow, and the flow rate is corrected by use of the value available at that time.

This invention is further described and illustrated in conjunction with the accompanying drawings which show embodiments by way of examples only.

Referring to the drawings:

Figure 1 shows diagrammatically a fluidic element used as a flow meter and fitted with a micro flow sensor,

Figure 2 shows an algorithm of the operating process,

Figure 3 shows an algorithm of the zero point correction of the flow sensor,

Figures 4 to 7 show graphically the method of zero point correction,

Figure 8 shows diagrammatically the known method for achieving gain correction, and

Figure 9 shows diagrammatically the method of achieving gain correction according to this invention.

Referring to Figure 1 of the drawings, a fluidic

flow meter is shown including a micro flow sensor which incorporates an error detecting circuit. The error detecting circuit operates by assessing the signals from both the micro flow sensor and the fluidic element and when the two flow signals overlap, in other words they indicate nominally a similar flow rate, a microprocessor monitors the signals and assesses whether an error exists in one or other of the flow measuring devices. The following parameters define the functioning of this circuit.

a) In the case when a flow rate signal higher than the preset flow rate input is only from the flow sensor.

b) In the case that when a flow rate signal higher than the preset flow rate input is only from the fluidic element.

c) In the case when a flow rate signal lower than the preset flow rate input is only from the flow sensor.

d) In the case when a flow rate signal lower than the preset flow rate input is only from the fluidic element.

Table 1 shows an example of error assessing criteria when the flow rate being measured by the fluidic element has been set to 150 litres/hour minimum and the flow rate being measured by the flow sensor has been set to the level from 0 to 150 litres/hour. The decision in this case is normal while in the other case one or other or

both devices are judged to be operationally abnormal.

Table 1

	Output of fluidic element	Output of flow sensor
over 150 litres/hour	Present	More than 700 pulses.
0 to 150 litres/hour	Absent	Less than 700 pulses.

The abnormality judgement method is further explained with reference to Figure 1, wherein 1 is a fluidic element which has a nozzle 2, flow attachment surfaces 3 and 3a, feedback flow channels 4 and 4a, and fluid oscillation detecting ports 5 and 5a.

A flow sensor 6 is provided in the floor of the nozzle 2 and the flow rate detected by this flow sensor 6 is converted into an electric signal by a converting circuit 7 and is fed to the flow rate measuring circuit 8.

A fluid vibration detecting sensor 9 communicates with the fluid vibration detecting ports 5 and 5a, and provides a flow rate signal from the fluidic element by converting the fluid oscillations detected by the detecting sensor 9. This signal is fed into circuit 8.

The circuit 8 converts the input electric signals into flow rate for integration and display. This circuit selects the fluidic element 1 of the flow sensor

6 on the basis of the preset flow rate value and includes the error detecting circuit where the output from the converting circuits 7 and 9 is used to judge the presence of error when a signal higher than the preset flow rate value is fed from the flow sensor 6 and when a signal higher than the preset flow rate is input only from the fluidic element 1, or else a signal lower than the preset flow rate is input only from the flow sensor 6 and a signal lower than the preset flow rate is input only from the fluidic element 1. Figure 2 shows the logic algorithm diagram for deciding the validity of the sensor signals.

In the event that an abnormality in operation occurs it is possible to issue either an alarm signal or else the measuring process of the meter can be terminated if the abnormality should continue over a defined period of time. In such a case, if the measurement returns to normal operation then the metering process can be continued or optionally terminated.

In the present invention the method serves to monitor the output of both the fluidic element and the flow sensor whereby any error detected will produce a warning signal to enable a possible abnormality in operation to be assessed. The measurement process cannot therefore be continued where a fault has occurred

such as disconnection, a short circuit or faulty contacts, as well as faults occurring in the oscillation sensing lines and the flow sensor connection or electronic circuit.

Figure 3 shows an algorithm of the zero point correcting method for flow sensor 6.

At the start, the estimated value Po of the flow sensor output when the flow rate is zero is set, the absolute value of the result of subtracting Po from the value P that was actually measured by the flow sensor is compared with the threshold value T_H, and if the pulse number is smaller than the value T_H, the said pulse number (output) is assumed to be the zero point of flow sensor for estimating the offset value and for conducting a zero point correction; if the pulse number is larger than the threshold value, the presence of flow is assumed and the flow rate is corrected by use of the correction value at that time without changing the offset value.

The correction method is explained by reference to Figures 4 (A) and (B).

It is assumed, as shown in figure 4 (A), that the initial characteristics of sensor, which was l_1 in the flow rate versus sensor output characteristics, drifted because of a manufacturing adjustment error, time change or the like, and the sensor output at zero flow rate

became P_d and the characteristics also shifted to the l_2. Now if the threshold value T_H in the correction algorithm is:

$T_H = P_m / 2$ P_m : Minimum necessary detected flow rate, then the sensor output during zero flow rate is P_d because the following conditions can be satisfied :

$T_H > | P_d |$

the mean value of sensor output is P_d if the flow rate is actually zero, so the zero point correction value Po gradually becomes as follows :

$Po = P_d$.

Therefore, if the output of the sensor is P when the flow rate is more than $Q_m / 2$ and has changed as shown in figure 4 (B), the sensor output $\hat{P}$ after correction becomes as follows:

$$\hat{P} = P - Po$$
$$= P - P_d$$

and the sensor characteristics l_3 at that time coincides with the original characteristics l_1.

In contrast, because a sensor output below $P_m / 2$ is cut off in the conventional system by the dead region, the drift error cannot be removed (Characteristics l_4 in Figure 4 (B).

On the other hand, when the gas meter has been installed at a dwelling, it is impossible to produce the

situation where the flow rate is zero by closing the shut-off valve and by a similar method to effect zero point correction, and hence the sensor output attributable to a very much lower flow rate to that of the detected flow rate cannot be discriminated from the zero point drift.

Now suppose that the micro flow rate Q_L is

$$|Q_L| < T_H \quad (= Q_m / 2)$$

as shown in Figure 5, then the zero point is corrected by the aforementioned algorithm, or corrected in the reverse direction by the sensor output P_L corresponding to Q_L as shown in Figure 6, resulting in the characteristics of L_6.

However, even in such a case the limit of erroneous correction becomes up to l_7 or l_8 even in the worst case as shown in Figure 7 by making the maximum value of correction quantity to be

$$\mathrm{Max}\,(|Po|) < P_m / 2.$$

Therefore, the sensor output at the instant of zero flow rate will not exceed P_m / 2 even in the case of the characteristics of l_7 and the sensor output at the time of flow rate Q_m can be more than P_m > 2 even with the onset of the characteristics of l_8, so the flow rate zero can still be discriminated from the flow rate Q_m and the leak detecting function of flow sensor will not be

inhibited.

In the case of a shift in the sensor characteristics, this can be completely corrected if the shift is less than the threshold value as described above, and the present invention can accommodate the spread of sensor characteristics during manufacture and even temperature dependency.

On the other hand, if there has been a leakage lower than the necessary detection lower limit, the correction will be made by mistake, but the current performance can be maintained by appropriately selecting the limit value of correction. Further, the zero point is maintained by using the mean output at the time of micro signal, the mean signal output during the absence of flow becomes zero, and no excessive integration will be made even if no dead region is used. As a result, a high reliability can be obtained in the case of a gas meter.

Additionally, because the correction of drift value at the zero point is used to correct also the shift of characteristics of the entire flow sensor, the measurement accuracy of the sensor can be enhanced.

The gain correcting method of this invention is now described.

Figure 8 shows the conventional method for correcting the accuracy of the flow sensor with one

correction.

Figure 9 shows the correction by arithmetically averaging the past corrected values of n-times ($n \geq 2$: integer).

Specifically, when the pulse output of flow sensor is P, the following relationship with the flow rate indicated value Q exists:

$$Q_{(FS)} = K^i_{(FS)} \quad P \qquad (1)$$

where $K^i_{(FS)}$ is the flow sensor gain at time i.

If the gas flow rate has entered the region to be corrected, and the measurement has been made by both the flow sensor and fluidic element.

$$K^i = \frac{Q_{(FD)}}{P^i} \qquad (2)$$

where P^i is the mean value of the number of pulses of the flow sensor during the correction period, and $Q_{(FD)}$ is the mean value of flow rate measured using the fluidic element. The conventional method performs the correction by adopting the value K^i obtained by Formula (2) as a new flow sensor gain. That is to say,

$$K^{i+1}_{(FS)} = K^i \qquad (3)$$

In contrast to this, the present invention performs the correction by using the following formula:

$$K^{i+1}_{(FS)} = \frac{1}{\_} (K^i + K^{i-1} + K^{i-2} \ldots$$

$$n$$

$$+ K_{i-n+1}) = \frac{1}{n} \sum_{j=o}^{n-1} K_{i=j} \qquad (4)$$

Therefore, the following effect is in accordance with the correction method of the present invention.

In the conventional method, the measurement accuracy during correction influences the accuracy of the gain correction itself, the measurement accuracy during correction needs to be increased, that is the measurement time needs to be extended in order to increase the accuracy of the gain correction, but as the gain correction is achieved by the mean value of many correction results in this invention, the accuracy of gain correction can be maintained even if the accuracy is poor around the time of individual corrections.

Furthermore, because it becomes possible to lower the measurement accuracy at each correction and the time necessary for correction can be shortened, the frequency of operation of the correction process increases.

Because the requirement for shortening the operating interval of the flow sensor during the correction can be eliminated, the power consumption during correction is not increased. For this reason, a timer for monitoring the correction interval becomes unnecessary.

There follows a further gain correction method for a

flow sensor for correcting the gain using the gain before correction and the weighted mean value of the gain estimated after correction used for correcting the gain of the flow sensor on the basis of the comparison flow rate measured by the fluidic element.

For convenience this method is explained in relation to the conventional gain correction method.

When the pulse output of the flow sensor is P, the following relationship with the measured flow rate value $Q_{(FS)}$ of the flow sensor exists:

$$Q_{(FS)} = K^{i}_{(FS)} \quad P \tag{5}$$

where $K_{(FS)}$ is the flow sensor gain at time i.

Suppose that the gas flow rate has entered the region to be corrected and the measurement has been made by both the flow sensor and fluidic element.

$$K^{i} = \frac{Q_{(FD)}}{P^{i}} \tag{6}$$

where P^i is the mean value of the number of pulses of the flow sensor during the correction period while $Q_{(FD)}$ is the mean value of the flow rate measured by the fluidic element. In the conventional method, the correction is made by adopting K^i obtained from Formula (6) as a new flow sensor gain. Namely,

$$K_{(FS)} = K^{i} \tag{7}$$

where $K_{(FS)}$ is the flow sensor gain at the point of

time i + 1.

In contrast to this, the present invention takes the flow sensor gain as

$$K^{i+1}_{(FS)} = K^{i}_{(FS)} + \alpha (K^{i} - K^{i}_{(FS)}) \qquad \alpha > 0 \qquad (8)$$

where the α is the weighted coefficient.

The correction method according to this invention has the following features.

Because, in the conventional system, the measurement accuracy during the correction has an influence on the accuracy of gain correction as it is, the measurement accuracy during the correction needs to be increased, (that is, the measurement time needs to be extended) so as to enhance the accuracy of the gain correction, but because, in this invention, the gain correction can be carried out from the mean value of many correction results, the accuracy of the gain correction can be maintained even if the accuracy is poor for individual corrections.

It is possible to reduce the measurement accuracy at every correction and the time required for the correction can be shortened, the frequency of the correction process also increases.

Moreover, because the need for shortening the measuring interval of the flow sensor during the

correction can be eliminated, there is no increase in power consumption during the correction. Therefore, the time of monitoring the correction interval becomes unnecessary.

What is required in advance is only the gain last time. For this reason memory in the correction circuit can be saved.

Furthermore, the optimisation can be effected without difficulty because there only exists a single parameter α.

CLAIMS

1. In a fluid flowmeter for measuring rates of flow higher than a preset rate by means of a fluidic element and lower than a preset rate by means of a flow sensor, a method for zero point correction of the flow sensor wherein the maximum value of the permissible shift is set as a threshold value and the number of output pulses is assumed to be the zero point of the flow sensor for establishing the shift only when the actual value of flow sensor output is less than the said threshold value and wherein if the number of output pulses is greater than the threshold value, the shift value is not updated assuming that there has been a flow, and the flow rate is corrected by use of the value available at that time.

2. A method for zero point correction of the flow sensor wherein the maximum value of the permissible shift is set as a threshold value and the number of output pulses is assumed to be the zero point of the flow sensor for establishing the shift only when the actual value of flow sensor output is less than the said threshold value and wherein if the number of output pulses is greater than the threshold value, the shift value is not updated assuming that there has been a flow, and the flow rate is

corrected by use of the value available at that time.

3. A fluid flowmeter having a method of zero point correction and constructed and arranged to function as herein described with reference to the drawings.

4. A method of correcting the zero point of a flow sensor substantially as described herein and exemplified by the drawings.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)** — 21 —	Application number GB 9323178.5
Relevant Technical Fields (i) UK Cl (Ed.M) G1G (GEX, GPKF, GPKX) (ii) Int Cl (Ed.5) G01F G01P	Search Examiner D J HARRIS Date of completion of Search 27 JANUARY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1-4

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).